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VERIFICATION OF A TRANSLATION

I, the below named translator, hereby declare that:

My name and post office address are as stated below ;

That I am knowledgeable in the English language and in the Japanese language, and that I believe the English translation of the annexed document is a true and complete translation.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Date

Dec 16, 2003

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[Document name] Specification

[Title of invention] Liquid crystal display device

[Claims]

[Claim 1]

A multi-domain alignment active-matrix liquid crystal display device comprising;

first and second transparent insulating plates arranged to oppose each other;

said first plate having disposed thereon a plurality of scanning lines and a plurality of signal lines, thin-film transistors provided in the vicinity of intersections between the scanning lines and signal lines, and pixel electrodes connected to the thin-film transistors;

said second plate having a black matrix provided with openings at areas that oppose said pixel electrodes, a color layer and counterelectrodes provided so as to oppose said pixel electrodes;

a liquid crystal being sandwiched between the opposing first and second plates and being controlled by voltage impressed across said pixel electrodes and said counterelectrodes;

wherein an orientation layer is provided on each pixel electrode of said first plate via an insulating film,

wherein said orientation layer is formed into a curved surface and orient molecules of the liquid crystal aligned

in a direction normal to the curved surface of said orientation layer, and

wherein columnar spacers are provided between the two opposing plates for regulating a panel gap therebetween.

[Claim 2]

The device according to claim 1, wherein said columnar spacer has an end portion on one side thereof that is disposed approximately at a center of said orientation layer formed on said first plate.

[Claim 3]

The device according to claim 2, wherein said orientation layer formed on said first plate defines a cavity recessed toward said first plate in a cross section taken along a line normal to said plate; and

wherein said columnar spacer has a diameter that becomes progressively smaller in the direction of said second plate.

[Claim 4]

The device according to claim 2, wherein said orientation layer formed on said first plate defines a protrusion directed toward said second plate in a cross section taken along a line normal to said first plate; and

wherein said columnar spacer has a diameter that becomes progressively larger in the direction toward said second plate.

[Claim 5]

A multi-domain alignment active-matrix liquid crystal display device comprising first and second transparent insulating plates arranged to oppose each other;

said first plate having disposed thereon a plurality of scanning lines and a plurality of signal lines, thin-film transistors provided in the vicinity of intersections between the scanning lines and signal lines, and pixel electrodes connected to the thin-film transistors;

said second plate having a black matrix provided with openings at areas that oppose said pixel electrodes, a color layer and counterelectrodes provided so as to oppose said pixel electrodes;

a liquid crystal being sandwiched between the opposing first and second plates and being controlled by voltage impressed across said pixel electrodes and said counterelectrodes;

wherein each of said pixel electrodes on said first plate and an orientation layer formed on said pixel electrode defines a curved surface, and

wherein columnar spacers are provided between the two opposing plates for regulating a panel gap therebetween.

[Claim 6]

The device according to claim 5, wherein said

orientation layer is adapted to orient molecules of the liquid crystal substantially at right angles to the planes of said plates, and

wherein said orientation layer is formed by oblique vapor deposition of SiO.

[Claim 7]

The device according to claim 5 or 6, wherein said columnar spacer has an end portion on one side thereof that is disposed approximately at the center of the pixel electrode formed on said first plate.

[Claim 8]

The device according to claim 7, wherein said pixel electrode formed on said first plate defines a cavity recessed toward said first plate in a cross section taken along a line normal to said first plate; and

wherein said columnar spacer has a diameter that becomes progressively larger in the direction toward said second plate.

[Claim 9]

The device according to claim 7, wherein said pixel electrode formed on said first plate defines a protrusion directed toward said second plate in a cross section taken along a line normal to said first plate; and

wherein said columnar spacer has a diameter that becomes progressively smaller in the direction toward said

second plate.

[Claim 10]

The device according to claim 8, wherein, on said first plate, a wiring layer is provided beneath said pixel electrode, and said wiring layer electrically connects a source electrode of the thin-film transistor and said pixel electrode.

[Claim 11]

The device according to claim 10, wherein said wiring layer extends in a direction substantially in agreement with the direction of a transmission axis of a polarizer provided on said first plate.

[Claim 12]

The device according to any one of claims 1 to 11, wherein liquid crystal molecules contiguous to the surface of the columnar spacer are aligned substantially parallel to the surface of said columnar spacer.

[Detailed description of the invention]

[0001]

[Field of the invention]

This invention relates to a liquid crystal display device and, more particularly, to a liquid crystal display device of the "divided alignments type", generally termed as multi-domain alignment (particularly, multi-domain-vertical-alignment) in which, by aligning the liquid

crystal molecules differently in each domain within a single pixel, the visual-angle characteristics of the respective domains compensate for each other to provide a wide viewing-angle characteristic.

[0002]

[Related art]

Widely known examples of liquid crystal display devices include those of the twisted nematic (TN) type and those which employ electrically-controlled birefringence (ECB). However, a problem with these conventional devices is that since the alignments of the liquid crystal molecules aligning under application of a voltage are uniform within a pixel, tonality differs depending upon the angle of view. A technique (multi-domain alignment) through which the directions of alignment of liquid crystal molecules in a single pixel are made to differ is available as a method of improving upon the visual-angle characteristic. With a liquid crystal device of this kind, the visual-angle characteristics of the multi-domains compensate for each other, as a result of which the characteristic is improved.

[0003]

Multi-domain alignment methods are described in the specifications of Japanese Patent Kokai Publication JP-A-Nos. 7-318940, 8-292423, 9-80399, 9-304757 and 9-21913. These examples of the prior art place surrounding walls

about a pixel and regulate the alignment of the wall surfaces to thereby realize an alignment that is symmetrical with respect to an axis perpendicular to a plate (substrate) at the center of the area surrounded by the walls. Multi-domain alignment is achieved as a result. Alternatively, protruding and recessed portions having axial symmetry with respect to the above-mentioned axis of symmetry are formed to correspond to the pixel, whereby similar multi-domain alignment is achieved.

[0004]

The art set forth in the specification of Japanese Patent Kokai Publication JP-A-8-292423 will be described with reference to Fig. 6. Fig. 6 is a sectional view showing one pixel of a conventional liquid crystal display device. As shown in Fig. 6, walls 23, 24 each comprising a resist or the like are formed on a plate 1 so as to surround a pixel electrode 22, and a recessed portion 25 consisting of a resist film is formed between the walls 23 and 24. A counterelectrode 26 is provided on a plate 2 on the opposite side of the device, and a projecting portion 27 is formed on the counterelectrode 26. The plates 1, 2 are arranged to oppose each other in such a manner that the recessed and projecting portions 25, 27 will have common axes of symmetry. If the gap between the plates 1, 2 is filled with a mixture of at least liquid crystal and a hardening resin and the

liquid crystal and hardening resin are caused to undergo phase separation, a liquid crystal area will develop in such a manner that the liquid crystal precipitates in the recess 25 or surrounds the protrusion 27. When this occurs, the liquid crystal molecules in the vicinity of the recess 25 or in the vicinity of the protrusion 27 become oriented with axial symmetry, such as in radiating form or in the form of concentric circles, with the axis being perpendicular to the plates.

[0005]

[Problems to be solved by the invention]

However, following problems arise with the example of the prior art described above.

[0006]

In the prior art, a first problem is that distribution of spacers generally used to maintain the panel gap between the plates is inappropriate. The reason for this is that the presence of spacers in the pixel areas tends to provide nuclei resulting in poor liquid crystal alignment, thereby greatly degrading the display characteristic. In contrast, if the spacers would be provided at portions where there are no pixels in order to avoid the problem of poor alignment, this increases the number of process steps.

[0007]

In the prior art, a second problem is the requirement

of process steps for mixing the hardening resin with the liquid crystal and causing phase separation and curing after the panel is filled. As a result, process load for forming the liquid crystal alignment is great.

[0008]

In view of the above problems, the present invention has been accomplished. Accordingly, a main object of the present invention is to provide a multi-domain alignment liquid crystal display device in which regulation of the alignment of liquid crystal molecules is carried out through a simple process and panel gap can be maintained in stable fashion.

[0009]

[Means to solve the problems]

In order to attain the above object, according to the present invention, there is provided a novel active-matrix liquid crystal display device. The device comprises generally first and second transparent insulating plates arranged to oppose each other, the first plate having disposed thereon a plurality of scanning lines and a plurality of signal lines, thin-film transistors provided in the vicinity of intersections between the scanning lines and signal lines, and pixel electrodes connected to the thin-film transistors, the second plate having a black matrix provided with openings at areas that oppose the pixel

electrodes, a color layer and counterelectrodes provided so as to oppose the pixel electrodes, a liquid crystal sandwiched between the opposing first and second plates being controlled by voltage impressed across the pixel electrodes and counterelectrodes. Further an orientation layer is provided on the pixel electrodes of the first plate via an insulating film, the orientation layer being formed into a curved surface and causing molecules of the liquid crystal to become oriented in a direction normal to the curved surface of the orientation layer, and columnar spacers for regulating panel gap are provided between the two opposing plates.

[0010]

In the above present invention, each columnar spacer has an end portion on one side thereof that preferably is disposed approximately at the center of the orientation layer formed on the first plate. In a case where the orientation layer formed on the first plate defines a cavity recessed toward the side of the first plate in a cross section taken along a normal to the plate, the diameter of the columnar spacer becomes progressively smaller in the direction toward the second plate. In a case where the orientation layer formed on the first plate defines a protrusion directed toward the side of the second plate in a cross section taken along a normal to the plate, the

diameter of the columnar spacer becomes progressively larger in the direction toward the second plate.

[0011]

According to the present invention, there is also provided an active-matrix liquid crystal display device generally comprising first and second transparent insulating plates arranged to oppose each other, the first plate having disposed thereon a plurality of scanning lines and a plurality of signal lines, thin-film transistors provided in the vicinity of intersections between the scanning lines and signal lines, and pixel electrodes connected to the thin-film transistors, the second plate having a black matrix provided with openings at areas that oppose the pixel electrodes, a color layer and counterelectrodes provided so as to oppose the pixel electrodes, a liquid crystal sandwiched between the opposing first and second plates being controlled by voltage impressed across the pixel electrodes and counterelectrodes. Further, the pixel electrodes on the first plate and an orientation layer formed on the pixel electrodes define curved surfaces, and columnar spacers for regulating panel gap are provided between the two opposing plates.

[0012]

In the above present invention, the alignment (orientation) layer is formed by oblique vapor deposition

of SiO, and molecules of the liquid crystal are oriented substantially at right angles to the plane of the plate. Each of the columnar spacers has an end portion on one side thereof that preferably is disposed approximately at the center of the pixel electrode formed on the first plate. In a case where the pixel electrode formed on the first plate defines a cavity recessed toward the first plate in a cross section taken along a normal to the plate, the diameter of the columnar spacer becomes progressively larger in the direction toward the second plate. In a case where the pixel electrode formed on the first plate defines a protrusion directed toward the second plate in a cross section taken along a normal to the plate, the diameter of the columnar spacer becomes progressively smaller in the direction toward the second plate.

[0013]

[Preferred embodiments of the invention]

In a preferred mode of a multi-domain alignment liquid crystal display device according to the present invention, a first plate (1 in Fig. 1) has a thin-film transistor provided at each point of intersection of a scanning line and signal line, a pixel electrode (8 in Fig. 1) connected to the thin-film transistor and an orientation layer (10 in Fig. 1) formed on the pixel electrode and defining a curved surface, a second plate (2 in Fig. 1) has three types of color

layers (13 in Fig. 1) that corresponding to the three colors R, G, B, an counterelectrode (14 in Fig. 1) provided so as to oppose the pixel electrode 8, and an orientation layer (11 in Fig. 1), a columnar spacer (12 in Fig. 1) for regulating the panel gap is provided between the two opposing plates 1, 2, and liquid crystal is sandwiched between the two plates and subjected to multi-domain alignment by the orientation layer 10 having the curved surface and the columnar spacer.

[0014]

[Embodiments]

Preferred embodiments of the present invention will now be described in detail with reference to the drawings.

[0015]

[First Embodiment]

A liquid crystal display device according to a first embodiment of the present invention will be described with reference to Figs. 1 to 3, in which Fig. 1 is a sectional view showing one pixel of a liquid crystal display device according to the first embodiment, Fig. 2 is a plan view of the one pixel and Fig. 3 is a sectional view showing one pixel of a liquid crystal display device in which the shape of the curved surface of an orientation layer differs from that of Fig. 1.

[0016]

A method of manufacturing the liquid crystal display device of the first embodiment will be described with reference to Figs. 1 and 2. First, a gate electrode 3 and gate wiring 18, which comprise a single layer or multiple layers of a metal such as Cr or ITO, are formed on the transparent plate 1 such as glass by a process such as sputtering and a photoresist step, and a gate insulating film 4 comprising the two layers of silicon oxide and silicon nitride is formed on the gate electrode and gate wiring by a process such as CVD. A semiconductor layer 5 comprising amorphous silicon (a-Si, n+a-Si) is then formed by a processing such as CVD and a photoresist step, and a drain electrode 6, source electrode 7 and drain wiring 19, which comprise a single layer or multiple layers of a metal such as Cr or ITO, are formed by a process such as sputtering and a photoresist step. The steps described thus far form the drain wiring, the gate wiring and a switching element.

[0017]

Next, the pixel electrode 8 comprising a transparent, electrically conductive film such as ITO is formed by a process such as sputtering etc. and a photoresist step. A recess is formed on the pixel electrode 8 by a transparent insulating film 9. Specifically, acrylic resin or polyimide resin, for example, is used as a thermoplastic material, a portion having a comparatively large film

thickness is formed on the pixel electrode 8 by a photoresist process, and then the oblique (or curved) surface and bottom of the recess are formed utilizing the thermoplasticity of the material. Next, the orientation layer 10 comprising a transparent insulating film which causes liquid crystal molecules to align perpendicular to the film surface is formed on the insulating film 9. Specifically, polyimide resin SE-1211 (manufactured by Nissan Kagaku K.K.) is applied to the insulating film 9 and the polyimide resin is heated (cured) under conditions that will suppress the thermoplasticity of the insulating film 9, thereby forming the orientation layer 10.

[0018]

The columnar spacer 12 comprising an insulating film is formed substantially at the center of the recess. The columnar spacer 12 preferably is made of a material that will cause the liquid crystal molecules to align parallel to the surface of the spacer, and it is desired that the side surface of the spacer 12 be slanted or inclined. The direction of inclination is decided so as to agree with the direction in which the liquid crystal molecules are caused to slant by the recess. In this embodiment, it is preferred that the inclination of the side surface of the spacer 12 be such that the diameter (cross section) of the spacer will broaden in the direction toward the plate 1. Specifically,

a column with vertical (upright or straight) side walls is formed from photosensitive acrylic resin or polyimide resin by a photoresist process. Then, when the column is heated for curing, the temperature is raised gradually to form the inclined surface (side wall). It is required that this process be performed under conditions that will suppress the thermoplasticity of the insulating film 9.

[0019]

The structure of the plate 2 on the opposite side of the device will now be described. If the device presents a color display, the color layers 13 are formed on the transparent plate 2, which consists of glass or the like. A transparent electrically conductive film, specifically, the counterelectrode 14, which comprises ITO, are formed on the color layer(s) 13 as by sputtering. Next, the orientation layer 11 comprising a transparent insulating film which orients the liquid crystal molecules to align perpendicular to the film surface is formed on the counterelectrode 14. Specifically, the orientation layer 11 is formed using polyimide resin SE-1211 (manufactured by Nissan Kagaku K.K.).

[0020]

Next, the plates (substrate) 1 and 2 with their orientation layers opposing each other are disposed substantially in parallel with a fixed spacing maintained

between them by the columnar spacer 12, and the gap between them is filled with a liquid crystal material whose dielectric anisotropy is negative. The material used is MLC-6608 (Merck). In this embodiment, adding a hardening resin to the liquid crystal material is unnecessary. However, hardening resin may be added if desired, as set forth in Japanese Patent Kokai Publication JP-A-8-292423.

[0021]

Optical films 15, 16 are affixed to the outer-side surfaces of the plates 1 and 2. The optical films 15, 16 each comprise a polarizer or a combination of a polarizer and an optical compensation film. The polarizers affixed to the plates are arranged in such a manner that the light absorption axes thereof are orthogonal to each other.

[0022]

In the embodiment described above, a recess is formed by the insulating film 9. However, a protrusion may be formed by the insulating film 9, as illustrated in Fig. 3. In this case the columnar spacer 12 may be formed on the plate 2 and it is preferred that the columnar spacer 12 be formed in such a manner that its side surfaces be inclined in a direction that narrows the spacer in the direction toward the plate 1. Other components are the same as those shown in Fig. 1. Though the planar structure of the pixel electrode 8 may be rectangular in general, a circular or oval

shape is preferred if matching with the recess or protrusion is taken into consideration. It is also possible to adopt a composite shape such as the combination of rectangular and circular shapes shown in Fig. 2.

[0023]

In terms of operation of the present Embodiment the following explanation is given. Now referring to Fig. 1, the pixel surface of the plate 1 defines a recess. In the initial state, which is devoid of applied voltage, the liquid crystal molecules are caused to orient generally perpendicular to the surface of the recess by the orientation layer 10. Accordingly, since the direction of an electric field produced when a potential difference develops across the pixel electrode 8 and counterelectrode 14 is substantially perpendicular to the surfaces of the plates, the direction of orientation of the liquid crystal molecules in the initial state tilts relative to the direction of the electric field.

[0024]

This direction of tilt agrees with the direction of tilt of the liquid crystal molecules oriented parallel to the surface of the columnar spacer 12. Since the liquid crystal molecules exhibit negative dielectric anisotropy, they tilt in a direction perpendicular to the electric field when voltage is applied. In other words, the tilt is

increased further in the initial direction of tilt, as indicated by the liquid crystal molecules 17 in Fig. 1. The transmittance of transmitted light is controlled by the angle of tilt. Since the liquid crystal molecules in one pixel tilt with the columnar spacer 12 (i.e., the axis thereof) serving as the axis of symmetry, the display characteristics of the respective directions of tilt compensate for each other even if the angle of sight (viewing angle) changes. This makes it possible to obtain a display in which there is little change in color at different viewing angles. The same effect can be obtained with the arrangement of Fig. 3 as well.

[0025]

[Second Embodiment]

A liquid crystal display device according to a second embodiment of the present invention will be described with reference to Figs. 4 and 5, in which Fig. 4 is a sectional view showing one pixel of a liquid crystal display device according to the second embodiment, and Fig. 5 is a sectional view showing one pixel of a variant liquid crystal display device in which the shape of the curved surface of an orientation layer differs from that of Fig. 4.

[0026]

The second embodiment differs from the first embodiment in that the pixel electrode 8 is provided on the

insulating film 9 and basically defines the shape of a recess; wiring 20 is an electrically conductive film, preferably a transparent film so as not to block transmitted light, formed by a process such as sputtering and a photoresist step (here, using ITO) so as to electrically communicate the source electrode 7 and pixel electrode 8; a film which orients the liquid crystal molecules perpendicular to the horizontal plane of the plates is adopted as an orientation layer 21 (and is formed, here, by oblique vapor deposition of SiO); and the direction of inclination of the side surface (wall) of the columnar spacer 12 is such that the cross section of the columnar spacer 12 narrows in the direction toward the plate 1.

[0027]

According to this arrangement, the pixel electrode 8 generally makes up or defines a recess. As a result, the electric field produced at application of voltage is not perpendicular to the horizontal plane of the plates but is nearly perpendicular to the curved surface of the recess. When the liquid crystal molecules would be oriented perpendicular to the curved surface in the initial state, therefore, as in the foregoing embodiment, the direction of orientation and the direction of the electric field substantially would coincide and the directions in which the liquid crystal molecules tilt would occur in random fashion,

thus causing a faulty display. Accordingly, it is desired that the liquid crystal molecules be oriented perpendicular to the plane of the plates in the initial state.

[0028]

In this arrangement, the direction of tilt of the liquid crystal molecule 17 differs from that of the first embodiment and, hence, the direction of inclination of the side surface of columnar spacer 12 also is changed accordingly. Further, the wiring 20 may be formed through a process the same as that used to fabricate the source electrode 7. In such case, use of a light-blocking electrically conductive film may be contemplated. However, a decline in transmittance can be suppressed by making the direction in which the wiring 20 extends agree with the direction of the light transmission axis of the polarizer as much as possible. Furthermore, by achieving electrical communication with the pixel electrode 8 at the bottom of the recess, it is unnecessary to separately provide an opening to effect such communication. This makes it possible to hold down any increase in the process load.

[0029]

Fig. 5 illustrates a variant case of Fig. 4 in which the insulating film 9 is made a protrusion instead of a recess. Similar effects can be obtained with this arrangement as well. Further, in Fig. 5, the insulating

film 9 is provided with a opening by a photoresist step in order to establish electrical communication between the source electrode 7 and the pixel electrode 8. However, depending upon the shape of the insulating film 9, the two electrodes can be communicated directly without forming an opening.

[0030]

[Effect of the invention]

The present invention provides the effects described below.

[0031]

The first effect is that the direction of alignment of the liquid crystal molecules can be regulated stably. The reason for this is that the columnar spacer is formed at the center of the recess or protrusion corresponding to a pixel, and the columnar spacer has a surface that slants in a direction that conforms to the direction in which the liquid crystal molecules are tilted. Furthermore, the liquid crystal molecules are oriented parallel to the slanted surface of the columnar spacer in the initial state. Since only a columnar spacer is present at the pixel portion of the device, faulty orientation or alignment does not readily occur.

[0032]

A second effect is a smaller process load. The reason

for this is that since the columnar spacer functions as both a column for regulating orientation of the liquid crystal molecules and a spacer for supporting (or retaining) the panel gap, the column and spacer can be formed by a single step. In addition, it is unnecessary to mix a hardening resin with a liquid crystal material in order for alignment of the liquid crystal to be achieved stably. This makes it possible to dispense with processes for phase separation and hardening.

[0033]

As a result of the effects set forth above, it is possible to obtain, through a comparatively simple process, a liquid crystal display device having a wide viewing in which there is little variance in tonality or gradation of individual pixels observed mainly when the visual angle is changed.

[Brief description of the drawings]

[Fig. 1]

Fig. 1 is a sectional view showing one pixel of a liquid crystal display device according to a first embodiment of the present invention;

[Fig. 2]

Fig. 2 is a plan view showing one pixel of a liquid crystal display device according to the first embodiment of the present invention;

[Fig. 3]

Fig. 3 is a sectional view showing one pixel of another structure of a liquid crystal display device according to the first embodiment of the present invention;

[Fig. 4]

Fig. 4 is a sectional view showing one pixel of a liquid crystal display device according to a second embodiment of the present invention;

[Fig. 5]

Fig. 5 is a sectional view showing one pixel of another structure of a liquid crystal display device according to the second embodiment of the present invention; and

[Fig. 6]

Fig. 6 is a sectional view showing one pixel of a liquid crystal display device according to the prior art.

[Explanation of the symbols]

1, 2: Plate

3: Gate electrode

4: Gate insulating film

5: Semiconductor layer

6: Drain electrode

7: Source electrode

8, 22: Pixel electrode

9: Insulating film

10, 11, 21: Orientation layer

12: Columnar spacer

13: Color layer

14, 26: Counterelectrode

15, 16: Optical film

17: Liquid crystal molecule

18: Gate wiring

19: Drain wiring

20: Wiring

23, 24: Wall

25: Recessed portion

27: Projecting portion